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APPENDIX C: Air Quality Guidelines

If particular contaminants are of concern or if the Indoor Air Quality Procedure is to be used, guideline concentrations are needed for the particular contaminants. At present, no single organization develops guideline concentrations for indoor air contaminants nor are values available for all contaminants of potential concern. A number of organizations offer guideline values for indoor air contaminants. These values have been developed for occupational and residential settings. They should be applied with an understanding of their basis and applicability to the indoor environment of concern. If a guideline concentration has not been published for a contaminant of concern, a value may be derived through review of the toxicologic and epidemiologic evidence and appropriate consultation. However, the evidence is likely to be insufficient for many contaminants. At present, there is no quantitative definition of acceptable indoor air quality that can be met by measuring one or more contaminants.

Guideline values for industrial environments developed by the ACGIH (threshold limit values, or TLVs) have been applied to indoor air contaminants (see Ref C-1; Ref C-2 is the German counterpart). This appendix provides 8-hour, time weighted average (TWA), 15-minute short term exposure limit (STEL), and instantaneous (ceiling) case limits. It is a source of concentration limits for many chemical substances and physical agents for industrial use. In light of the constantly changing state of knowledge, the document is updated annually. It cautions the user, "The limits listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use."

Caution should be used in directly extending the ACGIH TLVs or other workplace guidelines across other environments and to population groups other than workers. Industrial health practice attempts to limit worker exposure to injurious substances at levels that do not interfere with the work process and do not injure the worker's health. There is not an intention of eliminating all effects, such as unpleasant smells or mild irritation. The population is also different. Healthy workers tend to change jobs if they don't tolerate an exposure well. In contrast, the general population including children, asthmatics, allergic individuals, and the elderly may have less choice about where they spend most of their time or where they might even be confined. ...

Regulations are based on the results of accumulated experience with worker health and toxicologic research, carefully evaluated by groups of experts. Effects are examined in relation to exposure to the injurious substance. Exposure comprises both the concentration of the contaminant and the time during which exposure takes place. Since concentration may vary with time, exposure is typically calculated across the appropriate averaging time, expressed as a time-weighted average (TWA) concentration, short-term exposure limit (STEL), or ceiling limit. Regulations of the U.S. Occupational Safety and Health Administration (OSHA) are TWAs in most cases. Industrial exposures are regulated on the basis of a 40-hour work week with 8- to 10-hour days. During the remainder of the time, exposure is anticipated to be substantially lower for the contaminant of concern.

Scientists have discovered a number of ways that airborne chemicals can cause irritation of mucosal tissue such as that found in the human nose and the upper airways. These irritation responses can occur after the "irritant receptor" is exposed to non-reactive compounds, to reactive compounds with a different pattern of dose-response relationships, and through allergic and other immunologic effects for which dose-response relationships have not been well defined. The theoretical models of these irritation mechanisms have not yet found their way into standard setting processes. One reason for this may be the recognition of susceptible populations , i.e., individuals with atopy ("allergies") report irritation at lower levels of exposures than individuals

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without allergies. There also appear to be age and gender related differences in receptor responses to odorous and irritating substances.

For indoor contaminants for which a guideline value has not been established, one approach has been to assume that some fraction of TLV is applicable and would not lead to adverse effects or complaints in a non-industrial population in residences, offices, schools, etc. This approach should not be followed without assessing its suitability for the contaminant of concern. In any event, if standards or guidelines do not exist, appropriate expertise should be sought to evaluate the contaminant level that might prove acceptable.

Guidelines have been developed for outdoor air for a number of chemicals and metals, as shown in Refs C-3 through C-9. These values may be appropriate for some indoor environments but they should be applied only after appropriate consultation. These values also supply guidance concerning the quality of outside air, if there is suspicion that specific chemicals may contaminate the outdoor air or metals or a source is nearby.

Table C-1 lists target concentration guidelines for selected contaminants as general guidance for ventilation system design.

Table C-2 presents .selected standards and guidelines used in Canada, Europe, and the United States for acceptable concentrations of substances in indoor and industrial workplace environments. This table is presented as further background when using the Indoor Air Quality Procedure. Consultation may be warranted before selecting a particular value for use in calculating ventilation using the Analytical Ventilation Rate Procedure. Meeting one, some, or all of the listed values does not assure that acceptable indoor air quality will be achieved. These values are based on "cognizant authorities" and have not been developed by ASHRAE.

As they review the specific concentrations listed in this table, or others taken from the same sources, professionals should be mindful of the following:

- Standards are developed for different purposes and should be interpreted with reference to the setting and purpose for which they were developed compared to that to which they are being applied. .
- All standards do not necessarily recognize the presence of susceptible groups or address the "normal" populations.
- Most standards do not consider interactions between and among various contaminants of concern.
- The assumptions and conditions set forth by the standard may not be met in the space or for the occupants being considered (such as 8-hour day, 40-hour work week).

At times, selection of a specific target level is best made by a team with wide experience in toxicology, industrial hygiene, and exposure assessment. When many chemicals are present in the air, as they almost always are in indoor air, then some way of addressing potential additive effects is warranted. The ACGIH guidance on the subject (Appendix B, Reference C-1) instructs that when two or more substances acting on the "...same target organ system are present, their combined effect, rather than that of either individually, should be given primary consideration." If no contradictory information is available, the effects of the different substances "should be considered additive." A formula is given wherein the ratios of the concentrations of each substance to the threshold limit value for each substance are added. If the sum of all these ratios exceeds unity, then it is considered that the limit value has been exceeded.

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$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots \frac{C_n}{T} = \leq 1$$

Where
C = the airborne concentration of the substance
T = the Threshold Limit Value of that substance

TABLE C-1
TARGET CONCENTRATION GUIDELINES FOR SELECTED CONTAMINANTS

The contaminants listed in this table are common air contaminants of regulatory and health concern in non-industrial environments. The target concentrations have been set or proposed by various national or international organizations concerned with health and comfort effects of outdoor and indoor air, and are listed for reference only. The Table is not inclusive of all contaminants in indoor air, and achieving the target indoor concentrations for all of the listed substances does not ensure freedom from sensory irritation or from all adverse health effects for all occupants. However, field experience in buildings has generally shown that when thermal conditions meet ASHRAE Standard 55, when outdoor ventilation rates are equal to or greater than the minimum rates prescribed in this Standard, when moisture levels of indoor and HVAC surfaces are low enough to prevent microbial growth, and when the contaminants in this table are below the guideline levels, then air quality will be perceived as acceptable by a great majority of occupants.

Health or comfort effects and exposure periods that are the basis for the guideline levels are listed in the "comments" column. For design, the goal should be to meet the guideline levels continuously during occupancy, since people spend the great majority of their time indoors.

Users of this table should recognize that unlisted noxious contaminants can also cause unacceptable indoor air quality, both with regard to comfort (sensory irritation) and health. When such contaminants are known or expected to be present, selection of an acceptable level may require reference to other guidelines or a review and evaluation of relevant toxicological and epidemiological literature. (Table C-2 summarizes some of this literature.)

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Table C-1. Contaminants of Concern and Levels of Interest for Indoor Air

CONTAMINANT	SOURCES	LEVEL OF INTEREST	COMMENTS	REFERENCES
CARBON MONOXIDE (CO)	Leaking vented combustion appliances Unvented combustion appliances Parking garages Outdoor air	3 ppm above outdoor level (alert) 9 ppm (health)	Alert level an indication of abnormal indoor concentration; investigation of possible sources advisable. Health level based on effects on persons with coronary artery disease, average exposure for 8 hours.	C-9 [c] C-25 [m]
FORMALDEHYDE (HCHO)	Pressed-wood products Furniture and furnishings	120 $\mu g/m^3$ (0.1 ppm) 0.05 ppm	Based on irritation of sensitive people, 30-minute exposure (WHO). Based on irritation in allergic and asthmatic individuals (residential) (California Air Resources Board)	C-27 [c] C-25, 26 [m] C-32
LEAD (Pb)	Paint dust Outdoor air	1.5 $\mu g/m^3$	Based on adverse effects on neuropsychological functioning of children, average exposure for 3 months (WHO: 0.5-1 $\mu g/m^3$ for 1 year).	C-9 [c] C-9 [m]
NITROGEN DIOXIDE (NO_2)	Leaking vented combustion appliances Unvented comb. appl. Outdoor air	100 $\mu g/m^3$	Based on providing protection against adverse respiratory effects, average exposure for 1 year.	C-9 [c] C-25 [m]
ODORS	Occupants Fungal (mold) sources VOC sources Outdoor air	Predicted (or measured) acceptability to 80% or more of occupants or visitors	CO_2 concentration can be used as a surrogate for occupant odors (odorous bioeffluents). See Appendix F.2 for procedures to calculate appropriate setpoints as a function of occupancy density and occupant activity level. For sources other than people, source control is recommended.	C-28, 29, 30, 31 [c] C-25 (for CO_2), C-30 (for odor) [m]
OZONE (O_3)	Electrostatic appliances Office machines Ozone generators	100 $\mu g/m^3$ (50 ppb)	Based on potential for adverse acute and chronic effects, and an additional margin of protection, 8-hr exposure (WHO); continuous exposure (FDA)	C-16, 27 [c] C-16 [m]

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CONTAMINANT	SOURCES	LEVEL OF INTEREST	COMMENTS	REFERENCES*
	Outdoor air			
PARTICLES (PM_{10})	Dust Smcke Deteriorating materials Outdoor air	50 $\mu g/m^3$	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for 1 year, no 'carcinogens. Indoor concentrations are normally lower; guideline level may lead to unacceptable deposition of "dust."	C-9 [c] C-9 [m]
RADON (Rn)	Soil gas	4 pCi/liter	Based on lung cancer, average exposure for 1 year.	C-21 [c,m]
SULFUR DIOXIDE (SO_2)	Unvented space heaters (kerosene) Outdoor air	80 $\mu g/m^3$	Based on protecting against respiratory morbidity in the general population and avoiding exacerbation of asthma, average exposure for 1 year (WHO: 50 $\mu g/m^3$ if with PM)	C-9, 27 [c] C-9 [m]
TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCs)	New building materials and furnishings Consumable products Maintenance materials Outdoor air	<300 $\mu g/m^3$ (complaints unlikely) 300-3000 $\mu g/m^3$ (complaints possible) >3000 $\mu g/m^3$ (complaints likely)	Odor and irritation responses to organic compounds are highly variable. The three guidelines for this class of compounds represent ranges where odor and irritation complaints are seldom observed (comfort range); where complaints can become significant in buildings (comfort Û discomfort range); and where significant complaints are likely (discomfort range). Average indoor concentrations in most buildings are well below 1000 $\mu g/m^3$. The value for design should be selected by the designer and owner of the building. During operation of the building, measured TVOC concentrations above 1000 $\mu g/m^3$ should trigger further analysis to determine whether concentrations of individual compounds are above levels of concern.	C-31 [c] C-25 [m]

*** Key references that list the level of interest [c] and measurement methods [m].**

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TABLE C-2. Comparison of Guidelines and Standards Pertinent to Indoor Environments

The values summarized in this table include:

- Canadian: Recommended maximum exposures for residences developed in 1987 by a committee of Provincial members convened by the federal government to establish consensus, "guideline"-type levels. A revised version is being considered. These were not designed to be enforceable.
- WHO/Europe: Environmental (non-industrial) guidelines developed in 1987 by the WHO Office for Europe (Denmark).
- NAAQS: Criteria for outdoor air developed under the Clean Air Act by the US EPA. The guidelines must, by law, be reviewed every five years. These levels are selected to protect most sensitive individuals.
- NIOSH: Recommended maximum exposures for industrial environments developed by NIOSH (Centers for Disease Control). NIOSH criteria documents contain both a review of the literature and a recommended exposure limits (RELs) guideline. These are not enforceable and not reviewed regularly. These levels are not selected to protect most sensitive individuals.
- OSHA: Enforceable maximum exposures for industrial environments developed by OSHA (US Department of Labor) through a standard setting process. Once a standard has been set, levels can be changed only through reopening the rule-making process. These levels permissible exposure limits (PELs) are not selected to protect most sensitive individuals.
- ACGIH: Recommended maximum exposures for industrial environments developed by ACGIH's Threshold Limit Values (TLVs) Committee. The committee reviews the scientific literature and recommends exposure guidelines. The assumptions are for usual working conditions, 40 hour weeks, and single exposures. These levels are not selected to protect most sensitive individuals.
- MAK: Recommended maximum exposures for industrial environments developed by the Deutsche Forschungs Gemeinschaft, a German institutions akin to the National Institutes of Health, NIOSH, and the EPA. Levels are set on a regular basis, with annual reviews and periodic republication of criteria levels. These levels are enforceable in Germany. These levels are not selected to protect most sensitive individuals.

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- **TABLE C-2 Comparison of Guidelines and Standards Pertinent to Indoor Environments**[a]

	Canadian (ref. C-23)	WHO/Europe (ref. C-27)	NAAQS/EPA (ref. C-9)	NIOSH REL (ref. C-29)	OSHA (ref. C-12)	ACGIH (ref. C-1)	MAK (ref. C-2)
Formaldehyde	0.1 ppm [L] 0.05 ppm [L][b]	0.081 ppm [30 m]		0.016 ppm 0.1 ppm [15m]	0.75 ppm 2 ppm [15m]	0.3 ppm [C]	0.5 ppm 1 ppm [5m]
Carbon dioxide	3,500 ppm [L]			5,000 ppm 30,000 ppm [15m]	5,000 ppm 30,000 ppm [15m]	5,000 ppm 30,000 ppm [15m]	5,000 ppm 10,000 ppm [1h]
Carbon monoxide[c]	11 ppm [8h] 25 ppm [1h]	87 ppm [15m] 52 ppm [30m] 26 ppm [1h] 8.7 ppm [8h]	9 ppm[g] 35 ppm [1h][g]	35 ppm 200 ppm [C]	35 ppm 200 ppm [5m] 1500 [C]	25 ppm	30 ppm 60 ppm [30m]
Nitrogen dioxide	0.05 ppm 0.25 ppm [1h]	0.2 ppm[1h] 0.08 ppm [24h]	0.05 ppm [1y]	1 ppm [15m]	1 ppm [15m]	3 ppm 5 ppm [15m]	5 ppm 10 ppm [5m]
Ozone	0.12 ppm [1h]	0.08-0.1 ppm [1h] 0.05-0.06 ppm [8h]	0.12 ppm [1h]	0.1 ppm [C]	0.1 ppm 0.3 ppm [15m]	0.05 ppm 0.2 ppm [15m]	0.1 ppm 0.2 ppm [5m]
Particles[e] <2.5 MMAD[d]	0.1 mg/m^3 1h] 0.040 mg/m^3 [L]				5 mg/m^3	3 mg/m^3	
Particles[e] <10 MMAD[d]			0.05 mg/m^3 [1y] 0.15 mg/m^3 [24h][g]			10 mg/m^3	
Total Particles[e]					15 µg/m^3		
Sulfur dioxide	0.38 ppm [5m] 0.019 ppm	0.19 ppm [10m] 0.13 ppm [1h]	0.03 ppm [1y] 0.14 ppm [24h][g]	2 ppm 5 ppm [15m]	5 ppm	2 ppm 5 ppm [15m]	2 ppm 4 ppm [5m]
Lead	Minimize exposure	0.5-1.0 µg/m^3 [1y]	1.5 µg/m^3 [3 months]	<0.1 mg/m^3 [10h]	0.05 mg/m^3	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30m]
Radon		2.7 pCi/L [1y]	4 pCi/L [L][f]				2 ppm 4 ppm [5m]

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Notes for Table C--2

[a] [ ] Numbers in brackets refer to either a ceiling or to averaging times of less than or greater to 8 hours (m = minutes; h = hours; y = year; C = ceiling, L = long-term) Where no time is specified, the averaging time is 8 hours.

[b] Target level of .05 ppm because of its carcinogenic effects. Total aldehydes limited to 1 ppm.

[c] As one example, readers should consider the applicability of carbon monoxide concentrations. The concentrations considered acceptable for non-industrial, as opposed to industrial occupational, exposure are substantially lower. This is due to the recognition that individuals with pre-existing heart disease may develop exacerbation of heart disease at levels below 15 ppm.

[d] MMAD = mass median aerodynamic diameter in microns (micrometers). Less than 3.0 μm are considered respirable; less than 10 μm are considered inhalable.

[e] Nuisance particles not otherwise classified (PNOC), not known to contain significant amounts of asbestos, lead, crystalline silica, known carcinogens, or other particles known to cause significant adverse health effects.

[f] The USEPA has promulgated a guideline value of 4 pCi /L indoor concentration. This is not a regulatory value but an action level where mitigation is recommended if the value is exceeded in long-term tests.

[g] Not to be exceeded more than once per year.

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